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The Influence of Walking Speed on Hip Muscle Activity and Lumbopelvic Movement

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Introduction

As a result of the advent of the “desk job”, people today are more sedentary which can lead to serious chronic health problems (Tremblay, Colley, & Saunders, 2010, Waters & Dick, 2014). On average, office workers are sedentary for up to 75% of their workday (Thorp et al 2012). Sedentary lifestyles are linked to a higher risk for various chronic health issues including low back pain (Dunstan et al, 2012). Low back pain is the most prevalent musculoskeletal problem affecting 80% of US citizens at some point in their lives (Vallfors, 1985), yet 80% of all back pain problems are of unknown origin (Vogt, Pfeifer, Portscher, & Banzer, 2001). Workplace interventions that periodically interrupt sedentary working have been recommended to improve the overall health of employees (Dunstan et al, 2012). Some examples of common workplace adjustments are sit/stand workstations or treadmill desks (Davis & Kotowski, 2015). Recent findings may suggest that some individuals with low back pain have less lumbar rotation with walking, which could be facilitated as part of treatment (Gombatto et al 2015).

It is hypothesized that intermittent use of treadmill and sit-to-stand workstations may reduce musculoskeletal discomfort in office workers (John, Lyden, & Bassett, 2015). While these workplace interventions may have biomechanical and physiological benefits, they require employers to purchase additional equipment (John, Lyden, & Bassett, 2015). For those who have workplace flexibility, a potential solution would be to incorporate walking breaks into their workday. Breaking up prolonged sitting with walking breaks has been shown to have a positive effect on skeletal muscle gene expression involving cellular development and growth (Latouche et al. 2013), lessen workplace fatigue (Garcia, Wall, Steinhilber, Laubli, & Martin, 2016), elicit a better metabolic response (John, Lyden, & Bassett, 2015), and improve workplace brain function and cognition (Knight & Baer, 2014). In sedentary adults, disrupting sitting with as little as two minutes of light or moderate walking can improve glucose uptake and may contribute to weight loss, and can improve cardio-metabolic markers (Dunstan et al, 2012 & John, Lyden, & Bassett, 2015).

The benefits of walking have been repeatedly shown in research, including increased blood circulation, weight loss, increased nutrient uptake and storage in muscle tissue, and improved cardio-metabolic markers (John, Lyden, & Bassett, 2015). During walking, there is muscle co-contraction, the simultaneous activation of two muscles, that can improve spinal stability and for co-contraction to be beneficial, stability must increase more than spinal load. Low back pain or injury can be caused if spinal loading exceeds the muscle tissues tolerance (Granata & Marras, 2000). However, there is little information on how hip muscle co-contraction values in the biomechanics of the musculoskeletal system are influenced by changing walking speeds. Muscle co-activation has been shown to help in enhancing joint stability during movement regulation, as there is generally an increase in antagonistic co-activation in the trunk and lower extremity muscles as a function of walking gait (Lee, Chang, Choi, Ryu, & Kim, 2017). However, the influences of speed have not been shown on this action. Without this information, we cannot determine the potential walking break speed that would elicit the most favorable movement to reduce low back pain and discomfort as a result of prolonged sitting or standing. Past research does not show how speed influences gluteus medius co-contraction specifically, either. An increase in agonist-antagonist muscle co-contraction, especially in the gluteus medius, found in individuals with low back pain can correspond to an increase in spine loading (Granata & Marras, 2000), which in turn can create an altered muscle activation pattern (Nelson-Wong, Gregory, Winter, & Callaghan, 2008). Learning those influences will give us insight into how walking speeds affect the hip muscles and their activation.

In a study regarding self-selected speeds, the results revealed walking at slower speeds may be mechanically less efficient (Neptune, Sasaki, & Kautz, 2008), so it is assumed that this study will yield similar results in that there will be more muscular co-activation at speeds deviating farthest from the natural pendulum of body movement. Research shows a clear trend of decreased angular movements of the pelvis when walking at slower speeds (Taylor, 1999). Therefore, there is maximal hip muscle activity when there are increased angular movements while walking at higher speeds. It has been shown through gait analysis in a modeling study using 3D simulations of subjects that in the contributions of the gluteus maximus, gluteus medius, vasti, hamstrings, gastrocnemius, and soleus muscles increase as walking speed increased, especially the vasti and soleus (Liu, Anderson, Schwartz, & Delp, 2008). The gluteus medius primarily functions as a hip stabilizer and a pelvic rotator, in addition to their role in assisting with abduction (Gottschalk, Kourosh, & Leveau, 1989). The gluteus medius is active during the stance phase (heel strike) of walking, which fires all three segments of the muscle. The posterior part of the muscle fires at the beginning of the heel strike and continues through the point of the toe-off, while the anterior part shows maximum activity during the stance and single support stage (Gottschalk, Kourosh, & Leveau, 1989). Hip joint reaction forces are highly dependent on tensions developed by the hip musculature, so decreasing the need for gluteus medius contraction during gait will substantially decrease the joint reaction forces. Furthermore, the less gluteus medius contraction and joint reaction forces needed, the more stability the hip has, which contributes to lowering low back pain. During the single-limb support phase of gait, the gluteus medius on the stance hip provides a force that contributes to the stability of the pelvis (Neumann & Cook, 1985). Walking elicits cyclic movement of the lumbar spine and slow walking results in less movement than faster walking (Callaghan, Patla, & McGill, 1999);

however, this study did not have participants walk at standard walking speeds. Most studies allow participants to select their walking speeds themselves based on their natural walking gait and swing phases, which can create errors in the data analysis due to the lack of control of speed or stride length.

Therefore, the purpose of this study is to examine the effects of different walking speeds on lumbopelvic movement and muscular activation. This study will have equally representative male and female participants each walking at 3 randomly assigned speeds of 1 mph, 2 mph, and 3 mph. The selection of these speeds will allow us to determine the exact differences in hip muscle activation and lumbopelvic movement at increasing or decreasing speeds, instead of as a variable of individually chosen walking speeds. This study will provide information for researchers to make informed decisions on walking speeds used in future biomechanical studies. The study will aim to determine how changes in walking speed influence hip muscle co-contraction and lumbopelvic movement as a function of gait. It is hypothesized that the different walking speeds will change the muscle activation and joint angles of the pelvis and lumbar spine. Specifically, with an increase in walking speed up to 3 mph, it is hypothesized that there will be an increase in muscle activation and joint movement as well.

Methods

Participants: Seven individuals were recruited from the University aged population between 18 and 40 (mean age= 22.5). Three females and four males participated in this study. We collected demographic data including each participants age, height, and weight. Exclusion criteria included any previous low back or hip injury, surgery, chronic pain, an implanted pacemaker or cardioverter defibrillator, and an allergy to rubbing alcohol.

Procedure: Upon arriving to the Exercise Science Research Center, prior to any testing, the participants filled out a medical screening form and an informed consent form that had been approved by the Institutional Review Board. The participants all completed a baseline standing trial and three different walking trials at three different set speeds of 1 mph, 2 mph, and 3 mph. Each trial was 1 minute in its entirety. The order of speeds for each participant was randomized in order to prevent participants from adjusting to a systematically increasing workload as speed increased. During the walking trials, they were instructed to look straight ahead and walk in a relaxed fashion to ensure all participants data was recorded in the same fashion and no other movement factors interfered with the results.

Experimental Measures: We used electromyography to measure muscle activity for each one minute walking trial. Electrodes were placed on the bilateral gluteus medius and connected wirelessly to a computer system (Noraxon USA, Scottsdale AZ). Electromyography was collected at 2000 Hz. All data collections were processed with standard processing techniques. A cross-correlation index (CCI) was calculated to determine the simultaneous activation between the bilateral gluteus medius muscles to determine potential changes with walking speed. This methodology can be used to quantify spatial and temporal similarity between two time-varying signals and describe coordination with kinematics (Nelson-Wong & Callaghan, 2010). The cross-correlation index was calculated in Visual3D (C-motion Inc., Germantown, MD). A positive CCI indicates co-activation of the gluteus medius muscles. A negative CCI indicates reciprocal firing of the gluteus medius muscles.

Analysis: We used a one-way repeated measure ANOVA to test our hypotheses. The repeated factor was walking speed with levels of 0 mph (standing), 1 mph, 2 mph, and 3 mph. A Tukey post hoc test was used to assess differences between standing and the walking speeds. Significance was set at alpha= 0.05.

Results

There was a significant main effect of walking speed on CCI (p<0.0001). When walking at 1 mph, the CCI was -0.70 +/- 0.067. This was significantly different from the 0 mph (0.52+/-0.059, p<0.0001), 2 mph (0.38+/-0.059; p=0.0002) and 3 mph (-0.37+/-0.059; p=0.0002) conditions. There was no significant difference between the 2 and 3 mph conditions (p=0.9999).

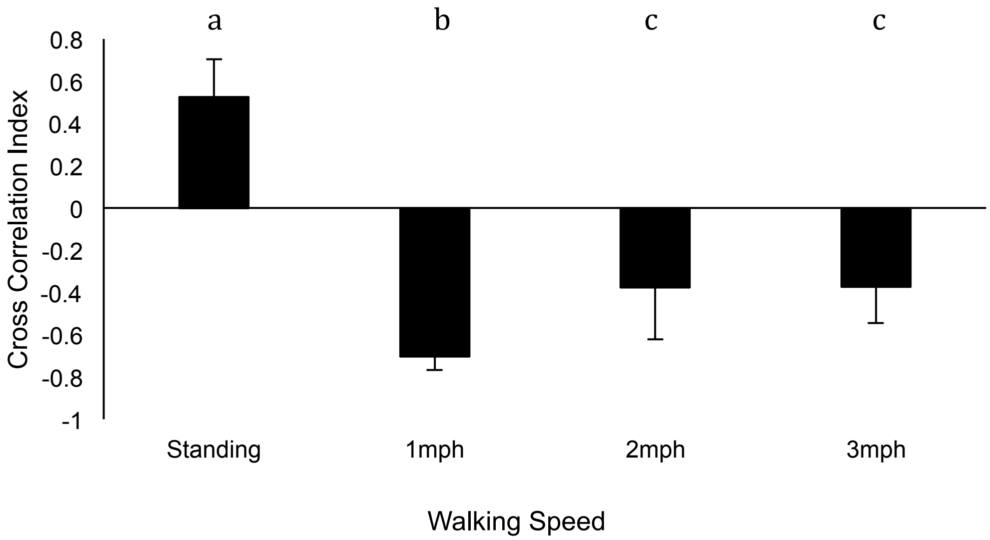

Figure 1: Cross correlation index (CCI) for each walking speed. Different letters denote significant differences between the walking speeds. Walking at 1 mph resulted in the most reciprocal firing of the gluteus medius, which was significantly different from standing, 2 mph, and 3 mph. The 2 mph and 3 mph conditions were not significantly different from each other. A positive CCI indicates co-activation of the gluteus medius muscles. A negative CCI indicates reciprocal firing of the gluteus medius muscles.

Table 1: The results from individual differences in cross-correlation indexes (CCI). Co-activation of the gluteus medius muscles is denoted by a positive CCI, while reciprocal firing of gluteus medius muscles are shown with a negative CCI.

Participant	Standing	1 mph	2 mph	3 mph
1	0.36	-0.791	-0.585	-0.504
2	0.397	-0.79	-0.615	-0.58
3	0.739	-0.701	-0.319	-0.37
4	0.632	-0.661	-0.469	-0.376
5	0.762	-0.661	0.0676	-0.047
6	0.399	-0.626	-0.202	-0.3-9
7	0.377	-0.689	-0.521	-0.434

Discussion/Conclusion:

Research has indicated that people who develop low back pain during standing have high gluteus medius co-activation, but there is no research on how interventions, such as intermittent walking breaks, influence co-contraction. The purpose of this study was to examine the effects of different walking speeds on muscular activation, specifically of the gluteus medius muscles. The results of this study could play a role in determining beneficial walking speeds for the reduction of prolonged standing induced low back pain. Our results support our hypothesis that the different walking speeds would change the muscle activation when compared to standing muscle activation. However, our results rejected our hypothesis that with an increase in walking speed up to 3 mph, there would be an increase in muscle activation. During the standing trial, the gluteus medius muscles were co-contracting, denoted by a positive CCI. As a result, walking did cause reciprocal firing of the gluteus medius muscles, indicated by a negative CCI. As speed increased, reciprocal firing was still evident, but not to the extent of that seen at 1 mph.

Our study used electromyography to look at the activation of the gluteus medius muscle because the gluteus medius had been shown to have higher co-contraction in individuals with low back pain associated with standing (Nelson-Wong & Callaghan, 2010). The gluteus medius is active during the stance phase, heel strike, of walking, which fires all three segments of the muscle (Gottschalk, Kourash, & Leveau, 1989). The posterior part of the muscle fires at the beginning of the heel strike through the point of toe-off. The anterior part shows maximum activity during the stance and single support stage (Gottschalk, Kourash, & Leveau, 1989). Our study indicated that the gluteus medius was the most active by reciprocal firing during the walking trial at a standardized 1 mph. We believe this could be due to the individual's need to walk at a slower than desired speed, resulting in a longer and more active muscle contraction during the stance and swing phases of walking. Another explanation could be that walking at 1 mph causes the individual to create exaggerated leg movements resulting in a deviation from the basic pattern of force with which leg movements are accelerated or decelerated during walking phases. The slower than average pace could require more than normal hip flexion or extension when accelerating or decelerating the swing leg (Zijlstra & Hof, 2003). The lengthened step duration during a slower walking speed could also play a role in the gluteus medius activation during the stance phase of the leg (Zijlstra, 2004).

Our results indicated that there was no significant difference in the gluteus medius activation during walking at 2 mph when compared to 3 mph. This could be due to the familiarity of those walking speeds. Research has indicated that the mean self-selected walking speed is between 2.88 mph and 3.12 mph (Mohler, Thompson, Creem-Regehr, Pick, & Warren, 2007; Bohannon, 1997). Walking at 2 mph and 3 mph likely creates similar patterns in leg movement during acceleration and deceleration. While walking at a faster 3 mph speed may result in higher peak acceleration or deceleration value, walking at 2 mph is most likely similar in value and pattern, especially compared to the difference between 2 or 3 mph and 1 mph walking.

One intervention for prolonged standing that has recently become more popular is the use of a treadmill desk that allows an individual to take walking breaks in their office or dual-task. The results of our study indicate that walking at 1mph, 2 mph, and 3 mph will increase reciprocal firing of the gluteus medius muscles, which is associated with reducing low back pain induced by prolonged standing. Our results show that walking at 1 mph creates the most significant difference from standing; therefore, an individual could walk at least as slow as 1 mph on their treadmill desk, which would allow them to be able to dual-task as well as reap the benefits of walking breaks in their work day; however, it is unknown what the prolonged effects of this would be, or if performing a secondary task, such as reading or writing, would change our results. It could also be possible that the 2 or 3 mph walking speeds provide adequate reciprocal firing, and that the insertion of a walking break between bouts of sitting or standing could be sufficient at helping to increase physical activity and reduce co-contraction.

There are several limitations of this study. While our work can be applied to the use of a treadmill desk, it is not a dual tasking study and therefore, did not study the effects of dual tasking on any aspect of walking or muscle activation. Each walking and standing trial was only 1-minute in its entirety, including 30 seconds of adaptation time and the latter 30 seconds being recorded with electromyography. Recording longer trials may be more indicative of the effects walking at the selected speeds may have on gluteus medius activation and prolonged standing induced low back pain due to fatigue associated with longer duration walking. Electromyography was only used on the gluteus medius muscles and therefore, we can not be sure of the effects of other deeper or surrounding muscles during walking. Another limitation of this study may be that we did not examine trunk muscle activation or postural effects on walking and the differences that may occur at the different walking speeds. While we asked participants how they were feeling in-between walking trials to ensure the safety and health of the participants, we did not establish a pain perspective scale during the trials.

Future work should assess the effects of a wider range of walking speeds, as well as walking at these speeds for an extended period of time to allow for fatigue to potentially play a role. More research should be done regarding the influence of trunk muscles and posture during walking and the differences in posture and muscle activation at different walking speeds. Future studies may include a subjective pain scale during the walking and standing trials to see the differences in muscle activation when compared to pain levels of the individual. Additionally, further research should be conducted on the effects of dual tasking with treadmill desks and an ideal walking speed to produce the reciprocal firing of the gluteus medius muscles, while allowing the individual to comfortably and efficiently complete their work.

In conclusion, all walking speeds demonstrated a tendency towards reciprocal firing of the gluteus medius muscles. There is a significant difference in the co-contraction index when walking at 1 mph when compared to walking at 0 mph (standing), 2 mph and 3 mph. There was not a significant difference in CCI when comparing walking at 2 mph and 3 mph. The 1 mph condition had a higher CCI indicating more reciprocal firing of the gluteus medius, which could be due to the distinct swing and stance phases and/or the lengthened step duration of walking at a slower than desired speed. Future work could combine these results with lumbar spine movement to help reveal potentially beneficial walking speeds for the reduction of prolonged standing induced LBP.

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